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AUTHOR BouJaoude, Saouma B.; Giuliano, Frank J.
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ABSTRACT

The main purposes of this study were to investigate the relationships among approaches to studying, prior knowledge, logical thinking ability, attitude, and performance in college freshman chemistry and to explore the effect of gender on the same variables. Subjects were 199 students (114 females, 85 males) enrolled in the second semester of a freshman chemistry course for non-science majors at a private university in New York State. Instruments used included seven subscales of the Approaches to Studying Inventory, the Attitude Toward Chemistry Questionnaire, and the Test of Logical Thinking (TOLT). The students' grades on an hour-long exam early in the semester were used as measures of the students' prior knowledge, while the semester cumulative final examination scores were used as measures of achievement in chemistry. Students in this study had slightly higher scores on reproducing orientation than on meaning orientation, a pattern that confirms Entwistle and Ramsden's (1983) findings with a similar group of non-science majors. The results of a stepwise multiple regression showed that prior knowledge, TOLT scores, and meaning orientation accounted for 32% of the variance on the final examination scores. (18 references) (Author/KR)

The Relationship Between Students' Approaches to Studying, Formal Reasoning Ability, Prior Knowledge, and Gender and Their Achievement in Chemistry

Saouma B. BouJaoude

Frank J. Giuliano

Department of Science Teaching

Syracuse University, Syracuse, NY 13244

Running Head: APPROACHES TO STUDYING

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The Relationship Between Students' Approaches to Studying, Formal Reasoning Ability, Prior Knowledge, and Gender and Their Achievement in Chemistry

Abstract

The two main purposes of this study were 1) to investigate the relationships among approaches to studying, prior knowledge, logical thinking ability, attitude and performance in college freshman chemistry; and 2) to explore the effect of gender on the same variables. Subjects for this study were 199 students (114 females, 85 males) enrolled in the second semester of a freshman chemistry course for non-science majors at a private university in New York State. Instruments used in this study included seven sub-scales of the Approaches to Studying Inventory, the Attitude Toward Chemistry Questionnaire, and the Test of Logical Thinking (TOLT). The students' grades on an hour-long exam early in the semester were used as measures of the students' prior knowledge, while the semester cumulative final examination scores were used as measures of achievement in chemistry.

Students in this study had slightly higher scores on reproducing orientation than on meaning orientation, a pattern that confirms Entwistle and Ramsden's (1983) findings with a similar group of non-science majors. The results of a stepwise multiple regression showed that prior knowledge, TOLT scores, and meaning orientation accounted for 32% of the variance on the final examination scores.

The Relationship Between Students' Approaches to Studying, Formal Reasoning Ability, Prior Knowledge, and Gender and Their Achievement in Chemistry

Introduction

The relationship among prior knowledge, formal reasoning ability, and achievement in science has been a topic of interest in science education research for several years (e.g. Chandran, Treagust, & Tobin, 1987; Lawson, 1983; Zeitoun, 1989). Lawson (1983) and Zeitoun (1989) established that the effect of prior knowledge on achievement exceeds that of formal reasoning ability. Conversely, Chandran et. al.(1987) found that the effect of formal reasoning exceeded that of prior knowledge. However, since science achievement can be measured in different ways, the seemingly contradictory results can be accounted for by the different tasks used to measure achievement (Falls & Voss, 1985). Consequently, the types of tasks used in measuring achievement must be clearly specified. Additionally, for research results to affect practice, the relationships between students' aptitudes and their achievement using regular classroom examinations taken in classroom settings must be investigated (Falls et al., 1985).

In another area of research, Clarke (1986), Entwistle and Kozeki (1985), Entwistle and Ramsden (1983), and Watkins (1983, 1984, 1986), investigated the relationships between students' approaches to studying and their achievement in different areas of the curriculum. Entwistle and Ramsden (1983) and Ramsden and

Entwistle (1981) interviewed many students to derive three main orientations to studying[1]: a meaning orientation (MO), a reproducing orientation (RO), and an achieving orientation (AO). Entwistle et al. (1983) described the meaning orientation as "deep approach out of interest" (p. 51), and the reproducing orientation as a "surface, instrumental approach" (p. 51). Achieving orientation was described as a "strategic approach" with "hope for success" (Entwistle & Kozeki, 1985). The studies reported by Entwistle et al. (1983, 1985) suggest that students' approaches to studying have significant relationships with achievement in different subject areas at both the university and high school level.

An important yet little understood area of research is the relationship between students' approaches to studying, prior knowledge, logical thinking ability, and attitude with achievement, as well as the relationships among the above variables and gender. Consequently, the two main purposes of this

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[1]In cognitive psychology research, the investigation of students' study processes is rooted in the idea of levels of processing (Craik & Lockhart, 1972; Craik & Watkins, (1973). On the other hand, the research of Entwistle & Ramsden (1983) is theoretically rooted in the tradition that derives categories of students' approaches to studying from qualitative analyses of students' reports of their own study processes.

study were 1) to investigate the relationships between approaches to studying, prior knowledge, logical thinking ability, attitude and performance in college freshman chemistry, taking into account the types of tasks used to measure achievement; and 2) to explore the gender differences on the same variables.

Method

Subjects

Subjects for this study were 220 students (128 females and 92 males, average age 18.9 years; 88.18% Whites/Caucasians, 6.82% African-Americans, 3.20% Oriental; 1.8% did not report their racial background) enrolled in the second semester of a freshman chemistry course for non-science majors at a private university in New York State. Fifty-six percent of these students graduated in the top 20% of their high-school class, 91% took at least one high-school chemistry class, and 26% took and passed the New York State Regents Chemistry Examination. Complete data were available for only 199 students (114 females and 85 males), because 21 of the original group dropped out of the course by the semester's end.

Description of the non-science majors' chemistry course

The topics covered in this chemistry course included: saturated hydrocarbons, unsaturated hydrocarbons, alcohols, phenols, ethers, aldehydes, ketones, carboxylic acids, amines, polymers, carbohydrates, lipids, amino acids, polypeptides, proteins, and nucleic acids and heredity. In addition, the course instructor incorporated the topics of genetic engineering, drug

abuse, and chemical pollution into his lectures.

The students met three times per week. Two of these meetings were reserved for lectures by the course instructor. The third meeting, typically held on Fridays, was conducted by graduate teaching assistants who reviewed the week's topics and answered students' questions. The students were also involved in bi weekly laboratory exercises on topics related to the lectures. Students' course grades were based on two hour-long exams, a cumulative final exam, and a laboratory grade. The two hour-long exams and the final exam were each composed of 25 multiple-choice questions and were machine-scored.

Instruments

The following instruments were used in the study:

a) Demographic Questionnaire. This was used to collect information about such variables as sex, age, racial background, ranking in graduating high-school class, parents' educational backgrounds, and number and type of chemistry courses taken at the high-school level.

(b) The Approaches to Studying Inventory. Seven of the 16 sub-scales (29 items)[2] from this instrument, which was developed by Entwistle and Ramsden (1983), were used to measure the students' approaches to studying. These approaches included: deep approach

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[2]See Entwistle and Kozeki (1985) for a similar design used to compare British and Hungarian adolescents.

(DA, active questioning in learning, four items); relating ideas (RI, relating ideas to other parts of topic under study, four items); intrinsic motivation (IM, interest in learning for learning's sake, four items); surface approach (SA, preoccupation with memorization, six items); syllabus boundness (SB, relying on teachers to define learning tasks, three items); extrinsic motivation (EM, interest in courses for the qualifications they offer, four items); and achievement motivation (AM, competitive and confident, four items)[3]. Students were asked to respond to the items in the questionnaire using a five-point Likert scale ranging from A (Always True, 5 points) to E (Never True, 1 point). All scores on the sub-scales were averaged, with a maximum score of 5. A meaning orientation (MO) score was computed by averaging students' scores on the deep approach, relating ideas, and intrinsic motivation sub-scales with a maximum score of 5. Also, a reproducing orientation (RO)[4] score was computed by averaging students' scores on the surface approach, syllabus boundness, and extrinsic motivation sub-scales, with a maximum score of 5. The sub-scales used in this study have reported internal consistency

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[3]The description in parentheses of each sub-scale was adapted from Entwistle et al. (1983).

[4]See Entwistle and Ramsden (1983) and Ramsden and Entwistle (1981) for a detailed discussion of the components of MO and RO.

reliability coefficients from .49 to .78 (Entwistle et al., 1983). In this study, these reliabilities ranged from .47 to .56 for all the sub-scales.

The following are examples of the items used in this instrument:

	Always True				Never True
I generally try hard to understand things that at the beginning seem difficult.	A	B	C	D	E
As I am reading new material in chemistry I try to relate it to what I already know on the topic.	A	B	C	D	E
While I am studying chemistry, I often think of real life situations to which the material I am learning would be useful.	A	B	C	D	E
I have to concentrate on memorizing a lot of what I have to learn.	A	B	C	D	E

(c) The Attitude Toward Chemistry Questionnaire (ATT). This instrument consisted of 10 items and used a semantic differential technique to measure students' attitudes toward chemistry. The directions of the 7-point adjective continua in the items were randomly altered to decrease the possibility of response set. An average rating, with a maximum of 7, was computed for each individual in this study. According to Mueller (1986), test-retest reliability coefficients and internal consistency coefficients of about 0.90 are not uncommon for instruments using semantic differentials. This instrument had an internal consistency reliability coefficient of .89 for this study.

d) Test of Logical Thinking (TOLT). Developed by Tobin and Capie (1981), this instrument consists of 10 items (five groups of two items each) selected to measure several components of formal thought; these include proportional (PROP), combinatorial (COMB), probabilistic (PROB), and correlational thinking (CORR), as well as controlling variables (CV). The 10 items of the TOLT contain two responses each - an answer as well as a reason for having selected the answer. Individuals must respond correctly to both components for the response to be considered correct. The TOLT has a reported internal consistency reliability coefficient of .84 and a value of .74[5] for this study.

Other sources of data for this study were the students' grades on the first hour-long exam and the final examination given in the spring semester of 1990. The first hour-long exam, used as a pretest (PRE), consisted of 25 multiple-choice questions and covered the pre requisite knowledge required for the course, as determined by the instructor. The difficulty indices of the questions on the first hour-long examination ranged from 0.21 to 0.93, with a mean difficulty index of 0.66. The discrimination indexes of the same items ranged from 0.06 to 0.75, with a mean discrimination index of 0.38. The internal consistency reliability coefficient of this test was 0.71. The course final

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[5]Zeitoun (1989) reports a reliability coefficient of .76 for the TOLT in a study with 17 and 18 year old students

examination (FINAL) was a cumulative examination that included 25 multiple-choice questions. The difficulty indices of the questions ranged from 0.11 to 0.95, with a mean difficulty index of 0.65. The discrimination indices of the test questions ranged from 0.15 to 0.90, with a mean discrimination index of 0.41. The final exam had an internal consistency reliability coefficient of 0.70. An analysis of the individual items on the final examination, using the description of knowledge as a taxonomy category provided in Bloom (1986), shows that all the questions were at the knowledge level.

Procedures

Students were asked to respond to the Demographic Questionnaire, the seven sub-scales of the Approaches to Studying Inventory, and the Attitude Toward Chemistry Questionnaire during a lecture in the first week of the 1990 winter semester. These same students were given the TOLT during the first and second weeks of the semester in their respective laboratory sessions. Additionally, the students' grades on the first hour-long exam and the second-semester final examination were obtained at the end of the spring semester (May 1990).

Results

Table 1 presents the means and standard deviations of the variables used in this study for the total sample, as well as for each gender. Tables 2, 3, and 4 present the means and standard deviations for the total sample and for females and males as a

function of formal reasoning ability.

Insert Table 1 about here

Insert Tables 2, 3, and 4 about here

Table 1 shows that students in this study have a higher score on reproducing orientation (RO) than on meaning orientation (MO). Moreover, Table 1 shows that the scores on the sub-scales of the meaning orientation and reproducing orientation are the highest for deep approach (DA) and syllabus boundness (SB), and the lowest score was on surface approach (SA). These patterns are evident for both female and male students. Also, Table 1 shows that female students have a higher meaningful orientation score (MO) than male students. However, this difference is not statistically significant at the .01 level ($t=-1.76$, $p<.07$), the alpha level set for the t-tests conducted in this study. Also, Table 1 shows that, while the scores of females on the sub-scales of the meaningful and reproducing orientations are consistently higher than those of males, none of these differences reached statistical significance at the specified alpha level. Also, there are no statistically significant differences between females and males on the scores for achievement motivation (AM). When TOLT scores are examined with respect to gender, there is a significant difference favoring male students ($t=2.4$, $p<.01$). Finally, no significant differences exist between male and female students on the final

exam scores (FINAL), pretest scores (PRE), and attitude scores (ATT).

Tables 5, 6, and 7 present Pearson correlation coefficients for the total sample, for male students, and for female students, respectively.

Insert Tables 5, 6, and 7 about here

Table 5 shows significant correlations between final exam scores (FINAL) and pretest scores (PRE), and meaning orientation (MO), and TOLT. In addition, there are significant correlations between, achievement motivation (AM) and meaning orientation (MO), achievement motivation (AM) and reproducing orientation (RO), attitude (ATT) and meaning orientation (MO), and attitude (ATT) and achievement motivation (AM). Finally, when correlations are computed for males and females separately (Tables 6 and 7), meaning orientation (MO) is significantly correlated with final exam (FINAL) for males but not for females; however, TOLT is significantly correlated with the final examination (FINAL) for both sexes.

Since the variables correlated with one another, a stepwise multiple regression analysis was applied to the data using the SAS Statistical Package, version 5, to determine which variable(s) were the best predictors of performance on the final examination (FINAL). Scores on the following served as predictors: a) meaning

orientation (MO); b) reproducing orientation (RO); c) achievement motivation (AM); d) pretest (PRE); e) TOLT; f) attitude questionnaire (ATT); g) and Gender. A second stepwise multiple regression was conducted using the sub-scales of meaning orientation (deep approach, relating ideas, and intrinsic motivation) and reproducing orientation (surface approach, syllabus boundness, and extrinsic motivation) as predictors. The results of the first multiple regression (Table 8) show that the pretest (PRE), TOLT, and meaning orientation (MO) are significant predictors of FINAL, accounting for approximately 32% of the variance on the final examination score; meaning orientation (MO) and the TOLT scores contributed significant, although small, prediction above the contribution of the pretest scores (PRE). The results of the second multiple regression (Table 9) show a similar pattern but with deep approach (DA) the only significant predictor among the sub-scales.

Since the patterns of correlations presented in Tables 6 and 7 differed for males and females, separate stepwise multiple regression analyses were conducted for the two groups. When MO, RO, PRE, TOLT, AM, and ATT were used as predictor variables, PRE, TOLT and MO accounted for approximately 34% of the variance on the final examination for male students; however, they accounted for only about 30% of the variance on the final examination for the female students (the difference being mainly due to the contribution of PRE. However, there were no differences between

males and females when the meaning orientation and reproducing orientation were replaced by their sub-scales.

Insert Tables 8 and 9 about here

Discussion

The results of this study confirm the findings of Lawson (1983) and Zeitoun (1989), who asserted that prior knowledge is the best predictor of achievement, followed by formal reasoning ability. The results of this study also confirm the findings of Entwistle and Kozeki (1985), Entwistle and Ramsden (1983), and Watkins (1983, 1984, 1986), who found a significant relationship between meaning orientation (MO) and achievement. Finally, the results confirm the findings from previous research (Baker, 1987; Walkosz & Yeany, 1984) that, on the average, males score higher than females on the TOLT.

The stepwise multiple regression shows that the meaningful approach scores (MO), as measured by the Approaches to Studying Inventory, allow a significant, although small, improvement over predicting of chemistry final examination scores (FINAL) solely by previous chemistry test and TOLT scores. This finding, coupled with similar research findings by Watkins (1983, 1984, 1986), indicates the possible importance of the approaches students use in studying to their success in chemistry. However, the relationship between students' approaches to studying and their achievement in chemistry may depend on the type of test used to

measure that achievement. The relationship may be weak if the test is designed to measure rote learning of facts, as in this study, rather than the acquisition of meaningful relationships between chemistry concepts.

According to Entwistle et al. (1985), "understanding depends upon on both comprehension and operation learning; the grasping of relationships has to be supported by an appropriate use of evidence and detail" (p. 136). Thus, it is important that students have a balance between a meaning orientation and reproducing orientation, and more specifically between a deep approach and a surface approach to studying. The lack of emphasis on either one of these approaches might be problematic. Total emphasis on meaningful learning and a lack of emphasis on rote learning may result an inadequate knowledge base necessary for their success in science courses.

Then, how do we explain why students have higher deep approach scores than surface approach scores, confirming Entwistle and Kozeki's (1985) research with British and Hungarian students, and that meaning orientation and deep approach rather than reproducing orientation and surface approach appear to be significant predictors of success on a chemistry examination that emphasizes rote learning? Part of this result might be explained by response set; that is, students may find it socially unacceptable to say that they memorize (Entwistle et al., 1985) when they really do; consequently, their surface approach and reproducing orientation

scores do not reflect their actual approaches to studying. Conversely, it can be argued that some of the students used their deep approach and meaning orientation to create meaningful links between the disparate facts emphasized by the examination and the course, which is reflected by higher scores on the final chemistry examination. Consequently, meaning orientation and deep approach appear to be significant predictors of freshman chemistry grades.

Implications for teaching

There are at least three implications that can be drawn from this study. First, the findings underscore the importance of both prior knowledge and logical thinking abilities as predictors of success in chemistry -- even in courses that emphasize and test rote learning -- with possible implications for emphasizing both in instruction. Second, approaches to studying may be important factors to consider, in addition to prior knowledge and logical thinking ability. For example, this study showed that a meaning orientation with a deep approach to studying is a significant predictor of success in chemistry, which suggests that students should be encouraged to actively question what they are learning and to relate ideas to other parts of the topic under study. Third, the Approaches to Studying Inventory might provide teachers with information about students' unbalanced study approaches; that is, it may identify students who favor a meaningful approach over a reproducing approach or vice versa, with implications for corrective work with these students.

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Table 1.
Means and Standard Deviations for All Variables Used in the Study for the Total Sample and Broken Down by Gender.

	Total Sample (N=199)		Females (N=114)		Males (N=85)	
	Mean	SD	Mean	SD	Mean	SD
FINAL	65.95	14.59	65.58	15.19	66.45	13.76
PRE	69.68	17.86	70.37	18.97	68.76	16.40
MO	3.18	0.47	3.22	0.43	3.11	0.50*
DA	3.53	0.52	3.59	0.48	3.47	0.58
RI	3.25	0.61	3.31	0.56	3.16	0.64*
IM	2.72	0.61	2.76	0.62	2.67	0.59
RO	3.30	0.34	3.31	0.37	3.28	0.30
SA	2.64	0.51	2.65	0.50	2.62	0.52
SB	3.52	0.57	3.55	0.54	3.49	0.60
EM	2.92	0.55	2.95	0.60	2.87	0.47
AM	3.54	0.61	3.52	0.59	3.57	0.64
TOLT	6.06	2.62	5.70	2.67	6.55	2.49**
PROP	1.44	0.83	1.34	0.87	1.57	0.75
CV	0.83	0.90	0.81	0.91	0.86	0.91
PROB	1.31	0.79	1.23	0.82	1.43	0.75
CORR	1.25	0.79	1.19	0.83	1.33	0.73
COMB	1.23	0.78	1.13	0.81	1.37	0.73
ATT	3.76	1.00	3.78	1.00	3.73	0.99

* $p<.07$
** $P<.01$

Table 2.
Meaning Orientation (MO), Reproducing Orientation (RO), Achievement Motivation (AM), Pretest (PRE), and Final Examination (FINAL) as a Function of Students' Formal Reasoning Ability for the Total Sample (N=199).

Tolt Range	Percent of sample	MO	SD	RO	SD	AM	SD	PRE	SD	FINAL	SD
0-2	13.1	3.31	0.42	3.36	0.44	3.40	0.63	67.04	20.39	63.04	14.48
3-4	17.6	3.12	0.57	3.24	0.43	3.53	0.68	67.33	14.92	61.73	11.83
5-6	21.2	3.18	0.43	3.34	0.26	3.60	0.56	66.48	19.15	63.07	14.81
7-8	28.4	3.18	0.38	3.30	0.32	3.62	0.55	70.07	20.03	67.40	16.02
9-10	19.8	3.13	0.55	3.26	0.30	3.46	0.68	76.19	12.21	72.19	12.80

Table 3.
Meaning Orientation (MO), Reproducing Orientation (RO), Achievement Motivation (AM), Pretest (PRE), and Final Examination (FINAL) as a Function of Formal Reasoning Ability for Female Students (N=114).

Tolt Range	Percent of sample	MO	SD	RO	SD	AM	SD	PRE	SD	FINAL	SD
0-2	16.4	3.21	0.38	3.32	0.47	3.31	0.63	64.67	21.70	60.89	15.00
3-4	20.3	3.22	0.54	3.28	0.47	3.57	0.60	67.00	14.98	61.17	11.94
5-6	17.2	3.30	0.37	3.40	0.31	3.66	0.54	71.78	15.61	65.47	14.25
7-8	32.0	3.21	0.35	3.30	0.30	3.61	0.53	71.11	23.05	66.33	17.77
9-10	14.1	3.14	0.57	3.25	0.31	3.29	0.67	78.12	12.42	71.06	12.77

Table 4.
Meaning Orientation (MO), Reproducing Orientation (RO), Achievement Motivation (AM), Pretest (PRE), and Final Examination (FINAL) as a Function of Formal Reasoning Ability for Male Students (N=85).

Tolt Range	Percent of sample	MO	SD	RO	SD	AM	SD	PRE	SD	FINAL	SD
0-2	8.7	3.57	0.43	3.49	0.31	3.64	0.57	73.14	18.29	68.57	12.31
3-4	13.0	2.81	0.45	3.13	0.33	3.44	0.88	61.18	14.79	61.67	11.87
5-6	26.1	3.07	0.47	3.29	0.19	3.54	0.58	62.61	21.32	61.91	15.15
7-8	23.9	3.13	0.44	3.31	0.36	3.65	0.58	68.00	12.27	65.56	12.05
9-10	20.3	3.13	0.56	3.27	0.29	3.58	0.67	74.89	12.14	72.96	13.03

Table 5.
Pearson Correlation Coefficients Between the Different Variables Used in the Study for Total Sample (N=199).

	FINAL	PRE	MO	RO	AM	TOLT	ATT
FINAL	1.00						
PRE	0.51*	1.00					
MO	0.16**	0.05	1.00				
RO	0.05	0.09	0.11	1.00			
AM	0.06	0.04	0.27*	0.23*	1.00		
TOLT	0.24*	0.16	-0.07	-0.07	0.05	1.00	
ATT	0.07	0.07	0.31*	-0.12	0.16**	-0.01	1.00

*P<.0005
**P<.03

Table 6.
Pearson Correlation Coefficients Between the Different Variables Used in the Study for Female Students (N=114).

	FINAL	PRE	MO	RO	AM	TOLT	ATT
FINAL	1.00						
PRE	0.50*	1.00					
MO	0.06	-0.16	1.00				
RO	0.00	0.03	0.03	1.00			
AM	0.06	0.02	0.32*	0.31*	1.00		
TOLT	0.26**	0.19***	-0.05	-0.07	0.03	1.00	
ATT	-0.04	0.02	0.34*	-0.11	0.08	-0.04	1.00

*P<.0005
**P<.005
***P<.05

Table 7.
Pearson Correlation Coefficients Between the Different Variables Used in the Study for Male Students (N=85).

	FINAL	PRE	MO	RO	AM	TOLT	ATT
FINAL	1.00						
PRE	0.53*	1.00					
MO	0.28**	0.26**	1.00				
RO	0.15	0.16	0.20	1.00			
AM	0.07	0.07	0.23**	0.13	1.00		
TOLT	0.22**	0.15	-0.05	-0.04	0.06	1.00	
ATT	0.22**	0.13	0.28**	-0.16	0.25**	0.05	1.00

*P<.0005
**P<.05

Table 8.
Stepwise Multiple Regression Summary for the Prediction of Performance on the Final Examination (FINAL) for the Total Sample (N=199).

Step	Variable entered	R^2	F	Prob>F
1	PRE	0.26	61.14	.0001
2	TOLT	0.30	9.03	.0030
3	MO	0.32	5.11	.0250

Table 9.
Stepwise Multiple Regression Summary for the Prediction of Performance on the Final Examination (FINAL) for the Total Sample (N=199) Using the Sub-scales of the Approaches to Studying Inventory AS Predictors.

Step	Variable entered	R^2	F	Prob>F
1	PRE	0.26	61.14	.0001
2	TOLT	0.29	9.04	.0030
3	DA	0.32	6.81	.0098